Telehealth in the United States
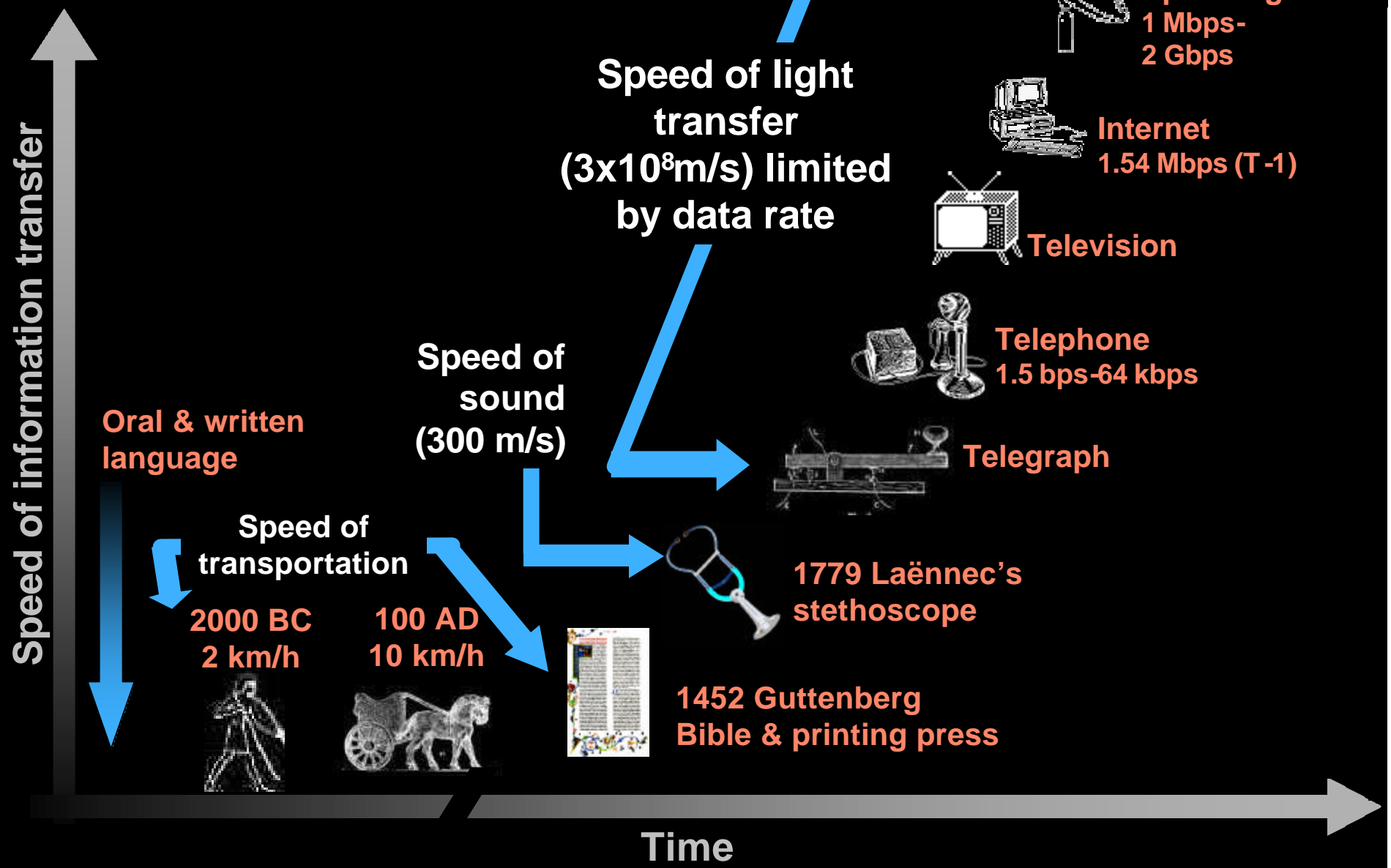
Arnauld E. Nicogossian, M.D.
Associate Administrator,
Office of Life & Microgravity Sciences and Applications,
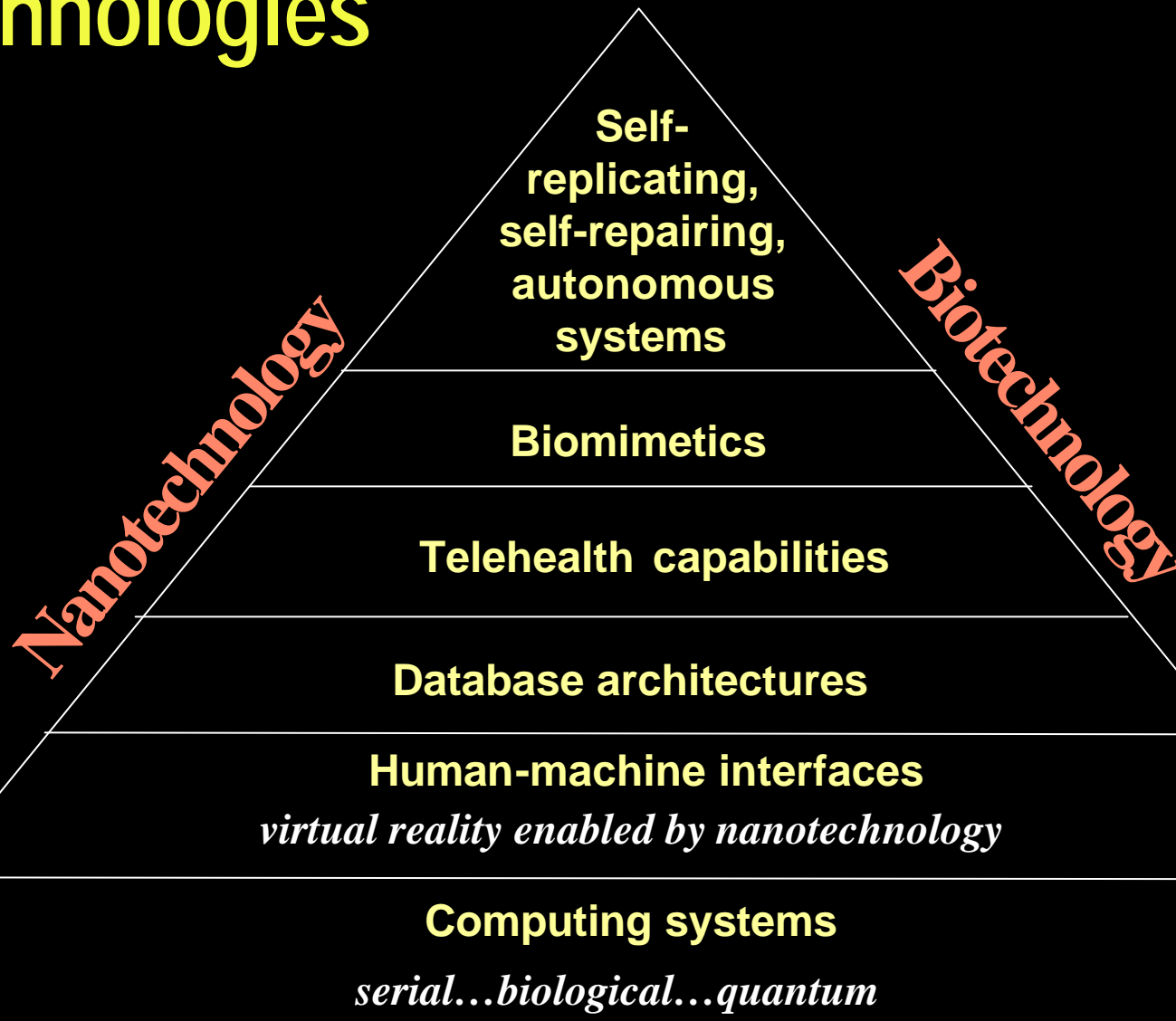**NASA**

Contents

- Telehealth in perspective
  - History
  - Technology
  - Philosophy
  - Requirements
- Telehealth in the United States
  - Civil sector
  - Department of Defense (DoD)
  - National Aeronautics and Space Administration (NASA)
- The future of telehealth in the U.S. space program
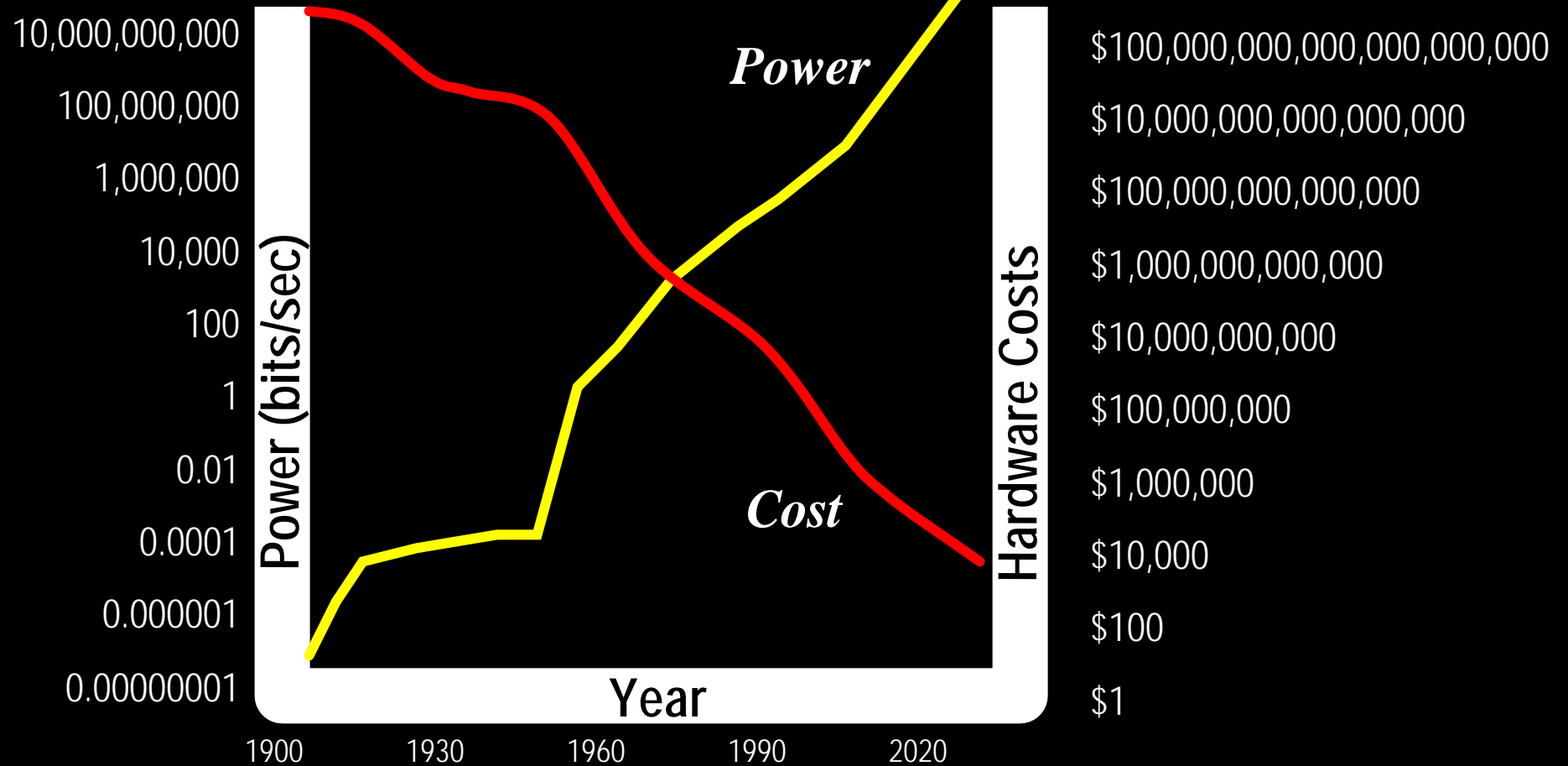
History of Communication & Telehealth

Speed of information transfer (vertical axis)

"Global Village" & Image compression, ????

Space Age 1 Mbps- 2 Gbps

Speed of light transfer $(3 \times 10^8 \text{ m/s})$ limited by data rate

Internet 1.54 Mbps (T -1)

Television

Telephone 1.5 bps-64 kbps

Speed of sound (300 m/s)

Telegraph

Oral & written language

Speed of transportation

2000 BC 2 km/h

100 AD 10 km/h

1779 Laënnec's stethoscope

1452 Guttenberg Bible & printing press

Time (horizontal axis)

Hierarchy of Medical Technologies

Nanotechnology

Biotechnology

Self-replicating, self-repairing, autonomous systems

Biomimetics

Telehealth capabilities

Database architectures

Human-machine interfaces
virtual reality enabled by nanotechnology

Computing systems
serial…biological…quantum

Information

Power vs. Cost of Computing

*Adapted from Hans Moravec, Mind Children:The Future of Robot and Human Intelligence (Cambridge, MA: Harvard University Press, 1988).

How Fast Can Data Move Today?

Telehealth

Application

| Paging 512 bps-1.2 kbps | Voice 64 kbps | Videoconferencing 128 kbps-1 Mbps | Video (MPEG) 1.54 Mbps | Hi-res imaging 8-100 Mbps | Virtual reality >100 Mbps |

narrowband *speed* broadband

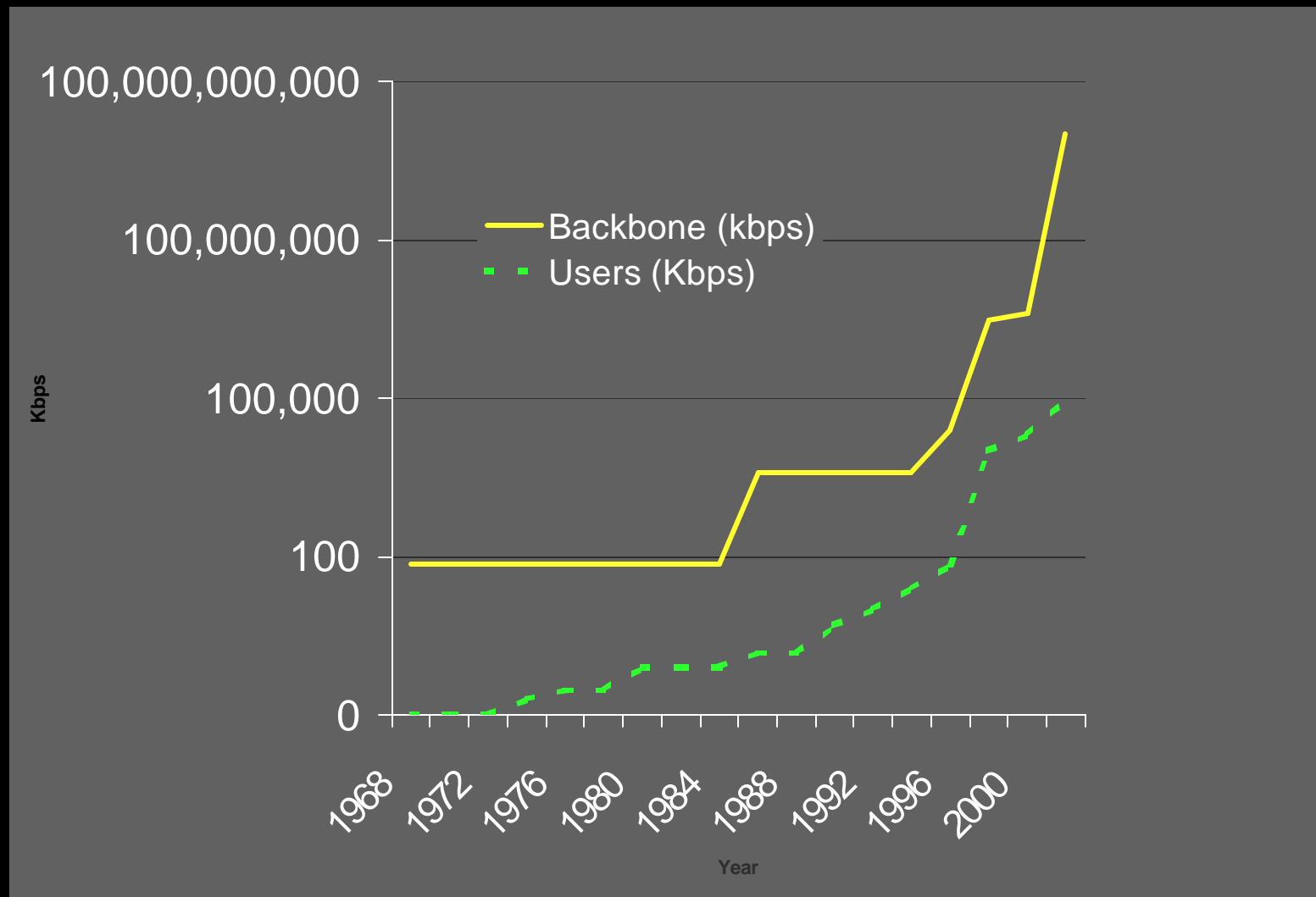| X.25 56-64 kbps | Circuit-switched pair 64 kbps | ISDN 128 kbps | T-1 line 1.54 Mbps | Ethernet network 10 Mbps | Satellite transponder 36 Mbps | ATM 622 Mbps |

Transmission method

1 Gigabit (Gb) = 1,000,000,000 bits
1 Megabit (Mb) = 1,000,000 bits
1 kilobit (kb) = 1,000 bits

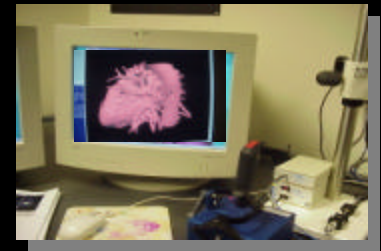Source: Futron Corporation, 1999

Growth of the Internet

100,000,000,000

100,000,000

Backbone (kbps)
Users (Kbps)

Kbps

100,000

100

0

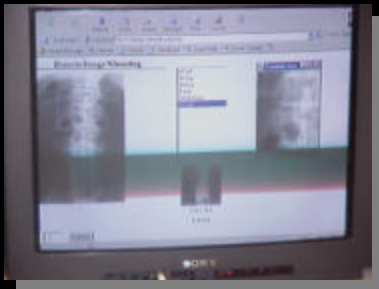1968 1972 1976 1980 1984 1988 1992 1996 2000

Year

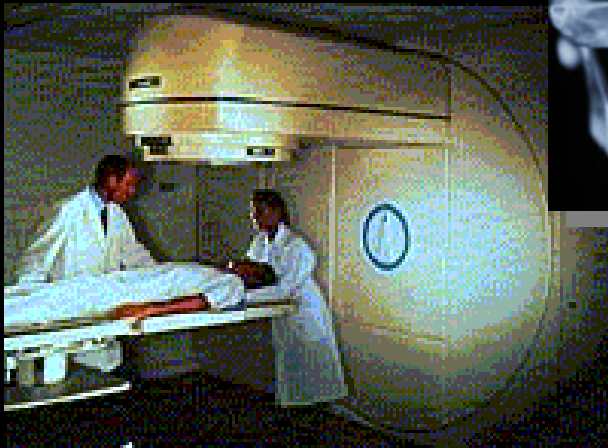# Telehealth Philosophy
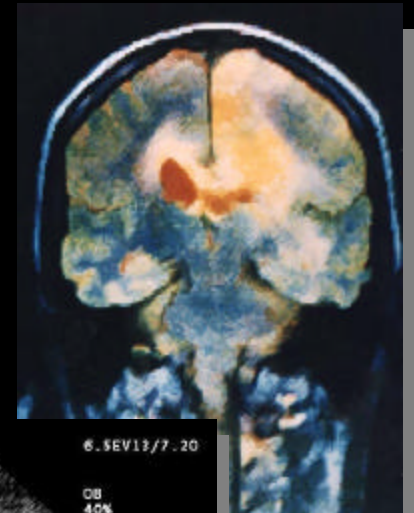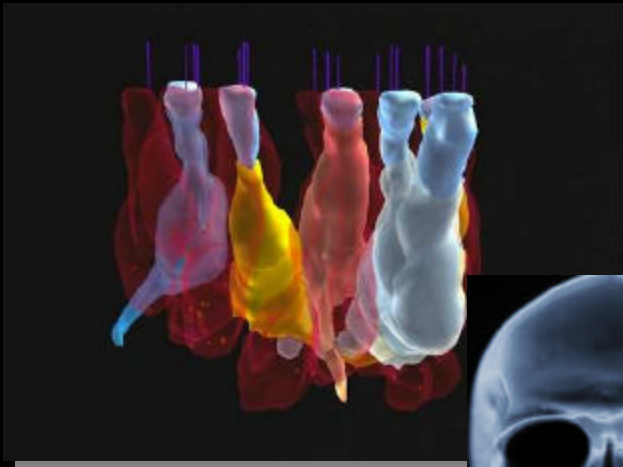
MONITOR

PREVENT

TREAT

Telehealth Requirements

- Improve traditional tools
- Minimize geographic inequality
- Enhance the quality of care
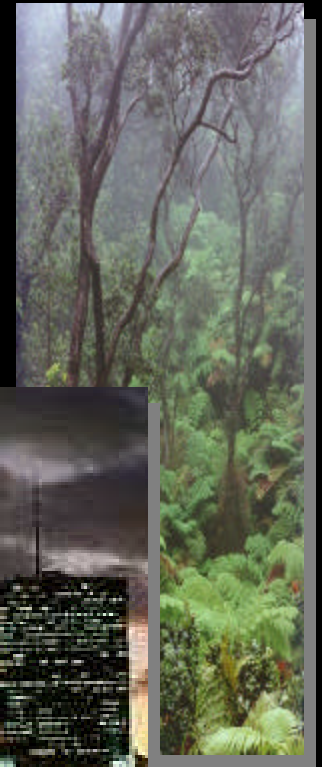- Contain expenditure/ infrastructure cost

Telehealth Requirements
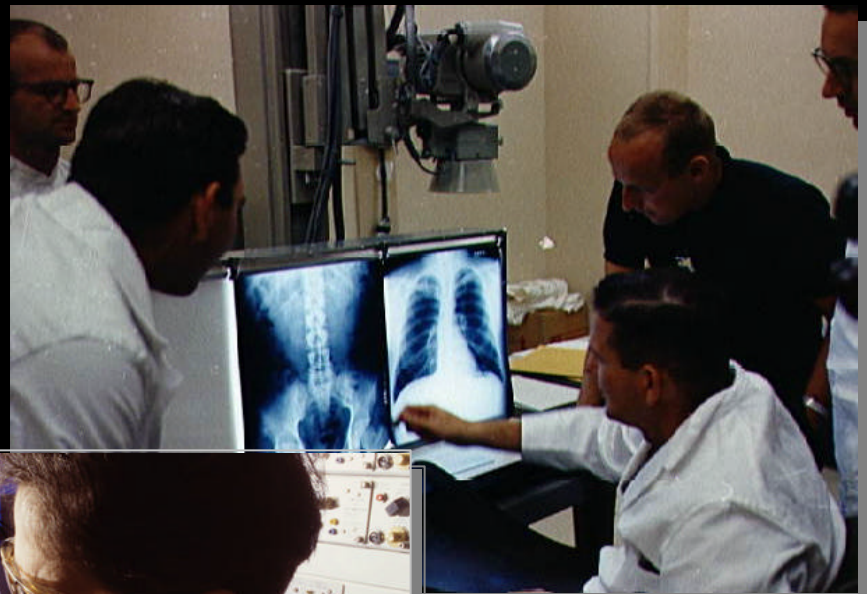
Improve traditional tools

Telehealth Requirements

Minimize geographic inequality

Telehealth Requirements

Enhance the quality of care

Telehealth Requirements

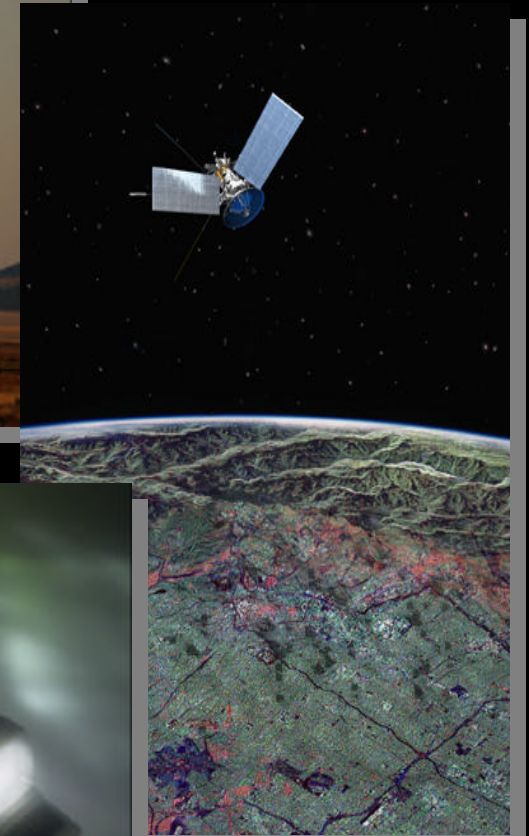## Contain expenditure/infrastructure cost
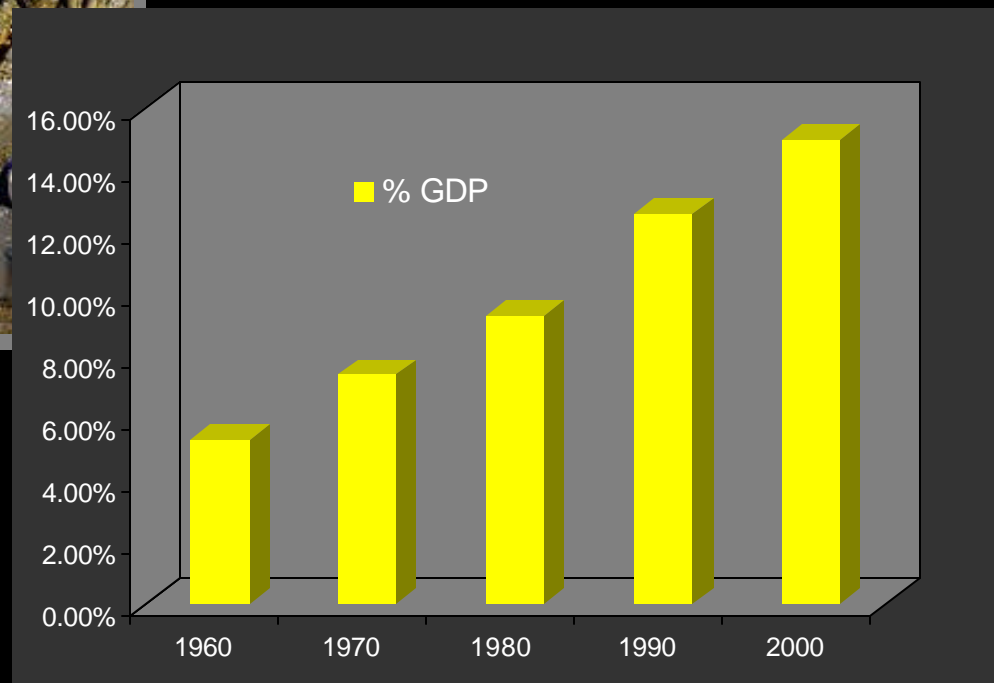
Historical U.S. Healthcare Expenditures

Telehealth Requirements

End-user infrastructure

Telehealth Requirements

Applications
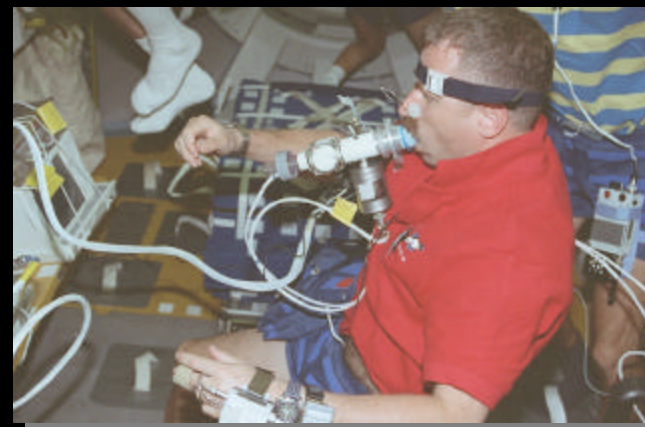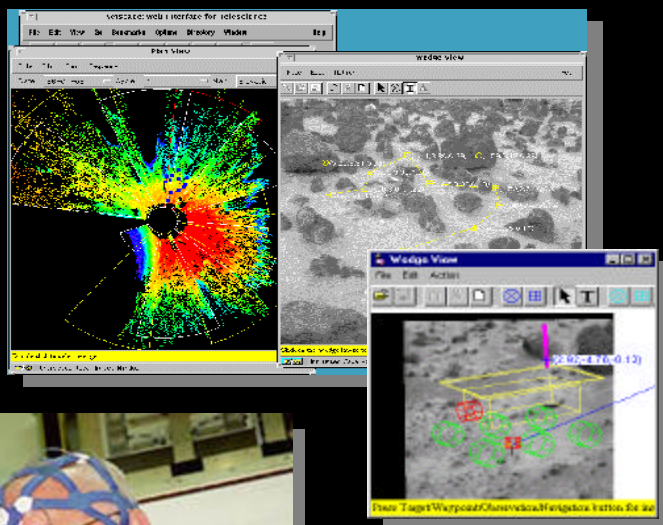
Telehealth

…moves bits, not patients.

Provider

Patient

World-Wide Web, Internet, & satellite

Teleradiology

Telepathology

Telesurgery

Telemonitoring

Telepsychology

Tele-epidemiology

Telepharmacology
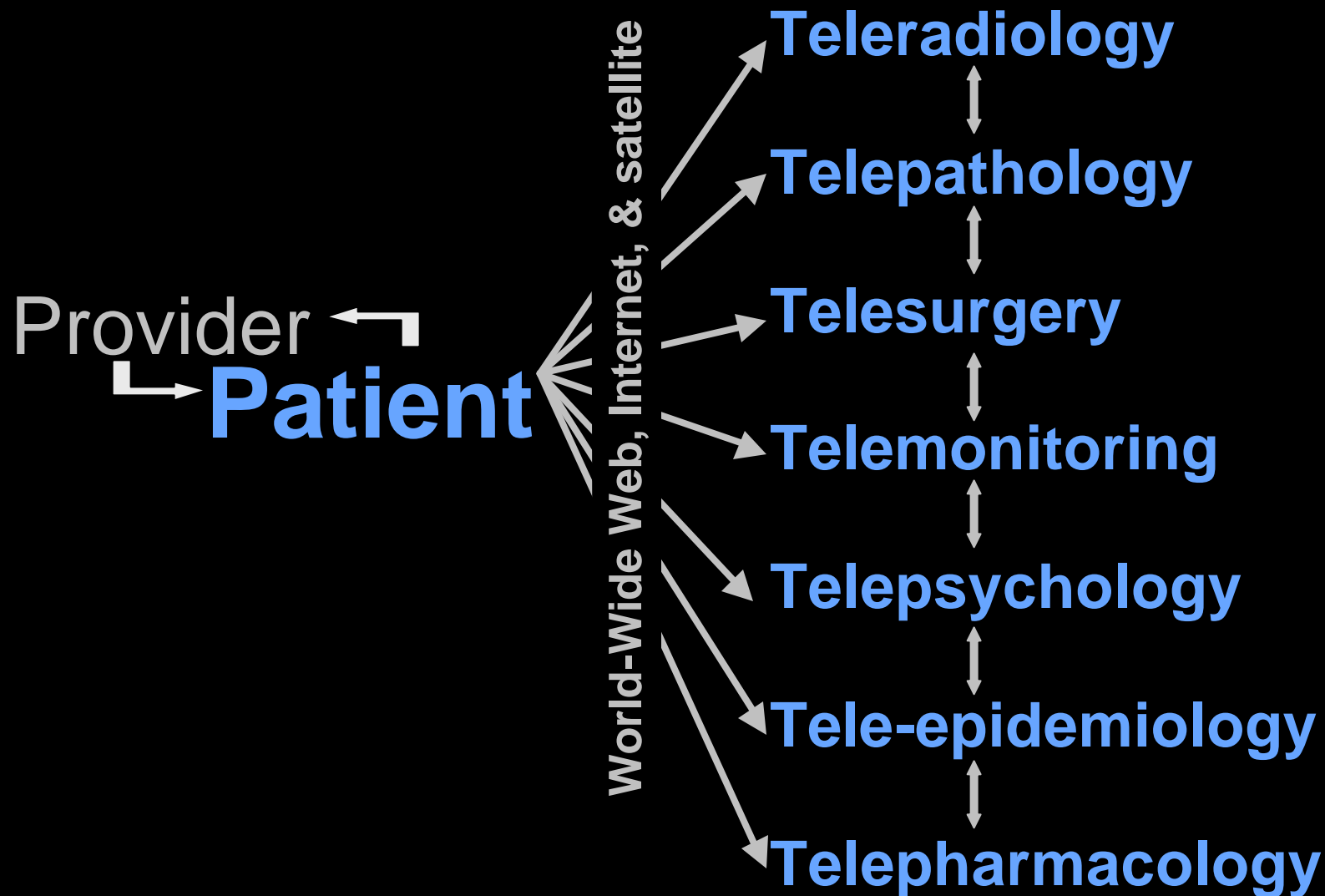
U.S. Telehealth: the Civil Sector

- Applications
  - EMS/rescue
  - Education ("Dot-Com" companies)
  - Teleimaging
  - Outpatient care/ home care
  - Maritime telecare
  - Prison telemedicine
  - Automated patient record systems
  - Disaster relief/humanitarian efforts

- Barriers
  - Security
  - Insurance reimbursement/liability
  - Medical licensure (across states)
  - Technology (bandwidth)

U.S. Telehealth: Dept. of Defense

- 1976: digital tooth
- 1985: digital x-rays
- 1990's: telepathology
- 1990's: teledermatology
- TATRIC (Army/NASA)
- Maritime telehealth (Navy)
- Deployments
  - Bosnia
  - Somalia
  - Persian Gulf
- Disaster relief

Lessons Learned from the DoD

- Telehealth works best with...

  - Full-time support

  - Reliable, mobile, user-friendly communications

  - Easy coordination

  - Information security

- Future considerations

  - Changes in health care patterns

  - Medical business reengineering

  - New technology

A Comparison: Who Does What?

	NASA	Civil Sector	DoD
Teleradiology	✔	✔	✔
Telecare/Telediagnosis	✔	✔	✔
Telepathology	✔	✔	✔
Telecardiology	✔	✔	✔
Teledermatology	✔	✔	✔
Tele-education	✔	✔	✔
Teleconsultation	✔	✔	✔
Telemonitoring	✔	✔	✔
Humans	✔		✔
Systems	✔		
Environment	✔		
Telescience	✔		
Testbeds	✔	✔	✔

NASA Mission Success

NASA Health Care Models

microgravity

Adaptation

- Red blood cell loss
- Fluid loss
- Cardiovascular adjustment
- Changes in neural control (blood pressure)

hypo-volemic syndrome

Pathophysiology

- Radiation
- Bone & muscle loss
- Immunology

degenerative diseases

Inflight

- *Human*
- *Systems*
- *Environment*

return to gravity

Post-flight

- Neurosensory motor control dysfunction
- $\downarrow$ cardiovascular reserve
- $\downarrow$ immune response
- Dehydration

cardiovascular & neurological compromise

- Regional osteopenia
- $\downarrow$ muscle endurance & strength
- $\uparrow$ risk of kidney stone(s)
- Radiation career dose exposure

health risks

NASA Health Criteria

- Maintain health and well-being before, during, and after mission

- Ensure rapid re-adaptation to gravitational forces

NASA Care Criteria

- **Ability** to treat crew members and return them to duty
- **Minimize** impact on remainder of crew
- **Provide** for stabilization and evacuation (in LEO)
- **Provide** for crew safety
- **Provide** for remote consultation

NASA Testbeds

- **Ground-to-ground**
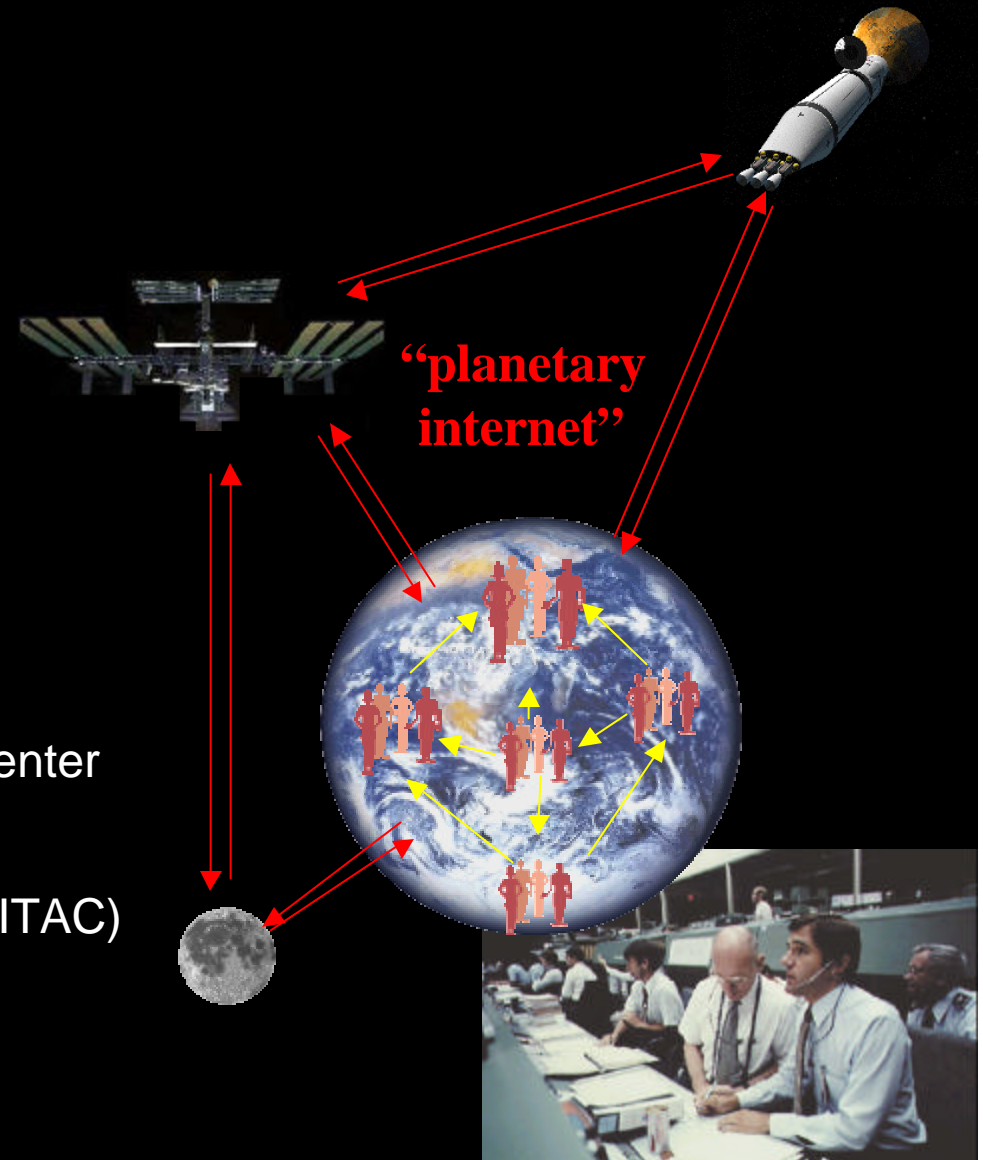 - Broadband
    - Satellite-based
    - Higher quality, higher cost
    - Spacebridge to Moscow
  - Narrowband
    - 5 kbs-45 Mbs
    - T-1 line
    - Good quality, lower cost
    - East-West Space Science Center
    - International public health
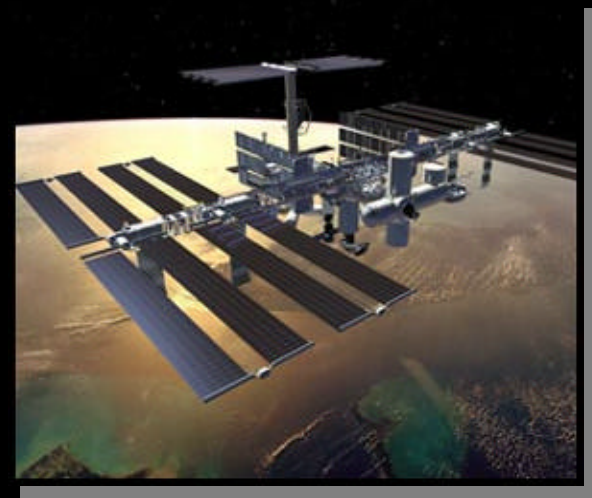   - Telepathology in Ecuador (MITAC)
- **Ground-to-flight**

"planetary internet"

NASA Communications Infrastructure

NASA ARC
Stanford
University
Salinas
Memorial
Hospital

Cleveland
Clinic

JSC

U Md East-West
Space Science Ctr

Loma Linda
University

CSC MITAC

Operation Strong
Angel (Pacific
Rim)

Jamaica

Dominican Republic

Ecuador

St. Petersburg

Tyumen

Moscow/FBC/MMSI/Zil/Tana

Kosovo
Toulouse

Ukraine

Greece

Georgia

Armenia

Novosobirsk

Egypt

Mt. Everest

East-West Ctr
Medsat coverage of
southern Africa

World Wide Web Links

Operational Links

Campaign Links

Planned

TDRSS

NASA Telehealth Applications

- **1961-1972**
  - Monitoring
  - Automation
  - Minimal command

- **1981-present**
  - Telemonitoring
  - Telescience
  - Teleimaging

- **2000+**
  - Telemonitoring
  - Telescience
  - Telecare
  - Teleimaging
  - Teleconsultation
  - Telediagnosis
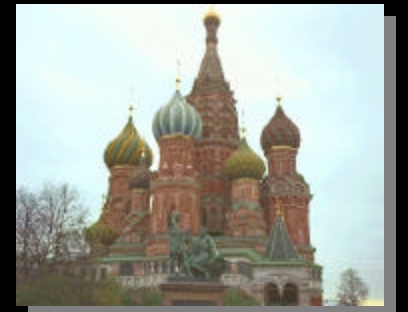
NASA Telehealth Applications

- **1972-3**
  - STARPAHC
- **1975**
  - Applied Technology Satellite
  - COSPAS/SARSAT
  - PEACESAT
- **1985**
  - Mexico City earthquake
- **1989**
  - Spacebridge to Armenia/Ufa
- **1993**
  - ACTS demonstrations
  - Spacebridge to Moscow
- **1994**
  - GHNet (WHO/USAID)
  - Pan-American Health Organization (PAHO)
  - Spacebridge to Russia (through 1997)
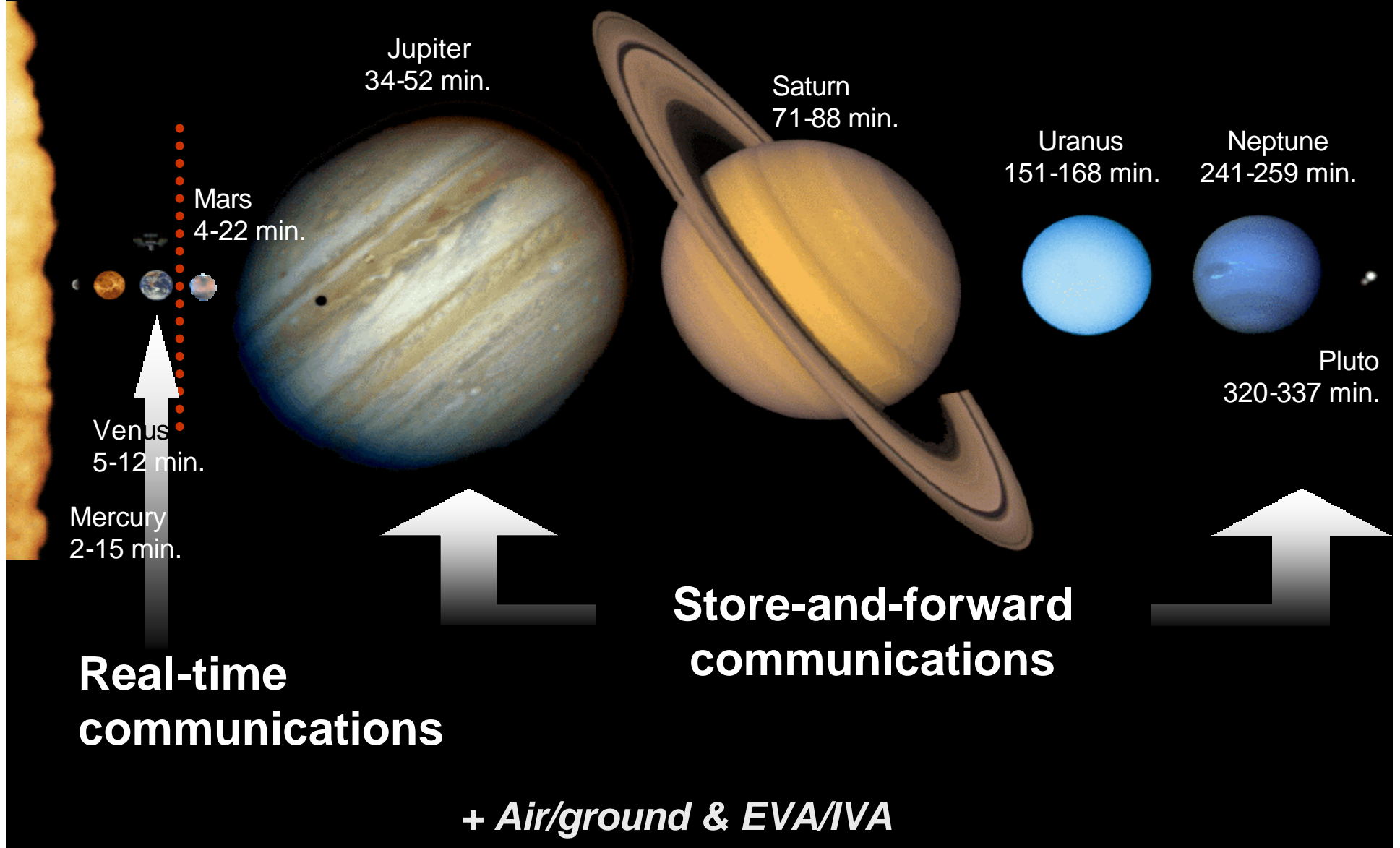
STARPAHC (ARIZONA)

✓ completed

NASA Telehealth Applications

- **1995**
  - ✓ ARC telemed demo with Trident & Mt. Sinai Medical Center

- **1997**
  - NASA-MITAC established
  - East-West Space Science Training Center

- **1998**
  - ✓ Ecuador "keyhole" surgery
  - ✓ Everest Extreme Expedition I

- **1999**
  - ✓ Virtual Hospital demo with ARC, Stanford, Salinas
  - ✓ Everest Extreme Expedition II
  - ✓ TIP demonstration in Texas and Montana

- **2000**
  - Low-bandwidth telemonitoring in Ecuador
  - Low bandwidth telemonitoring in Dominican Republic
  - Kosovo disaster response
  - Devon Island telemedicine

✓ *completed*

Communications Challenge: Time and Space

Jupiter
34-52 min.

Saturn
71-88 min.

Uranus
151-168 min.

Neptune
241-259 min.

Mars
4-22 min.

Pluto
320-337 min.

Venus
5-12 min.

Mercury
2-15 min.

Real-time communications

Store-and-forward communications

+ Air/ground & EVA/IVA
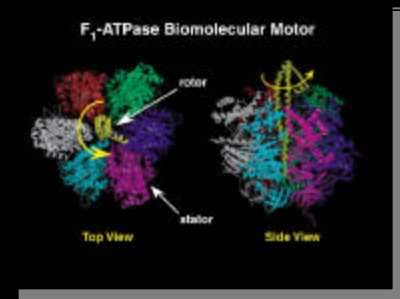
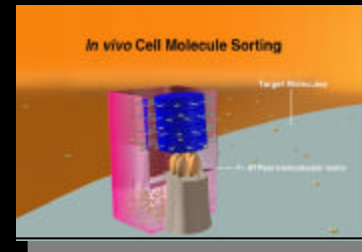# Future of Telehealth & the U.S. Space Program

From telecare to autonomy and teleconsult...

- Adaptive Automation
- Multipurpose Tactile Interface
- Maintaining Spacecraft Operator Alertness
- Performance Measurement, Evaluation, and Modeling
- Non-Invasive Video Motion Capture of Astronaut Activity

- Cognitive Prostheses
- Biologically-Inspired Robots
- Manipulation & Locomotion
- Functionally-Adaptive Biomimetics
- Wireless Biosensor
- Medical informatics
- Smart/haptic systems
- Telescience

Hair cell sensors

Biomotors

In vivo Cell Molecule Sorting

F_1-ATPase Biomolecular Motor

rotor

stator

Top View   Side View

NASA Telehealth

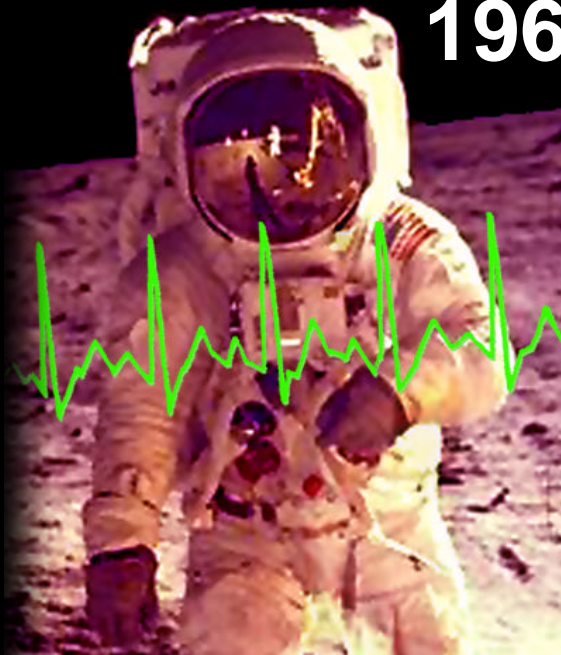Initial NASA telehealth efforts monitored survivability in microgravity.

Today, all aspects of NASA telehealth--communications, capabilities, and applications--improve health care in space and on Earth.

Conclusion

1924

1969

2000+

The insight we have gained from U.S. telehealth, combined with tomorrow's nanotechnology and informatics, will allow NASA to send astronauts on safe, productive long-term explorations.

Backup

NASA's Health Criteria

Medical standards are tailored to meet the specific needs of each class: pilot (I), mission specialist (II), or payload specialist (III).

Evaluation approach

- Selection criteria
  - Medical history and physical
  - Lab & functional testing
- Retention criteria
  - Health maintenance
  - Acceptance of certain risks with changes

Areas of Emphasis

- Short-duration mission
  - Neurosensory
  - Neuromotor
  - Cardiovascular/ cardiopulmonary
  - Fluid & electrolyte
- All missions
  - Performance
  - Psychosocial suitability
  - Survival
- Long-duration mission
  - All short-duration concerns
  - Musculoskeletal
  - Radiation exposure
  - Metabolic/endocrine
  - Hematology/immunology